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Research Article

Factors influencing technology integration among mathematics educators in South Africa: A modified UTAUT2 perspective

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ABSTRACT

Educators must effectively integrate technology into their teaching practices in today's technology-driven world. This study investigated factors influencing technology integration into teaching among mathematics educators in Gauteng secondary schools in South Africa. The unified theory of acceptance and use of technology, extended by adding the technological pedagogical content knowledge (TPACK) framed the study. Data was collected using an online questionnaire from 309 mathematics educators. Exploratory and confirmatory factor analyses were used to validate and verify the measurement model. The structural equation modelling analyses indicated that hedonic motivation (HM), performance expectancy (PE) and TPACK influenced behavioral intention (BI) to integrate technology. TPACK, facilitating conditions (FC), effort expectancy (EE), social influence (SIN), descriptive norms (SID) and habit (HT) influenced the behavioral use (BU) of technology integration. The second-order structural modelling indicated that all the constructs contributed to technology integration. Still, TPACK was the most important, with the highest explained variance of 64.4%, followed by EE, FC, HM and HT, which all had explained variances above 50%. BI and BU, PE and social influence contributed less than 50% of the explained variance. Our findings could provide insights into future interventions for effective technology integration for in-service educator training.

Keywords: TPACK, facilitating conditions, technology integration, effort expectancy, mathematics

INTRODUCTION

Despite the substantial investments and the provision of digital tools such as interactive whiteboards (IWBs), smartboards, internet-enabled devices and Wi-Fi (Dlamini, 2022) by the Gauteng provincial educational department (Mlambo et al., 2020), many mathematics educators are not effectively integrating these tools into their teaching (Avci, 2022; Graham et al., 2020; Mihai, 2020; Perienen, 2020; Saal & Graham, 2023; Zulu, 2020). This occurs against a background of low academic achievements in mathematics in South African schools at the national and international levels (Gaillard, 2019; Graham et al., 2021; Reddy et al., 2019).

Notably, the successful integration of technology into teaching is associated with positive or improved learner academic achievement in mathematics learning (Mailizar et al., 2021; Ndlovu & Meyer, 2019). For instance, interactive technology increases engagement, leading to student motivation (Cirneanu &

Moldoveanu, 2024); tools such as graphing calculators and simulations lead to better visualization of complex mathematical concepts (Ozudogru & Ozudogru, 2019; Yildiz & Arpaci, 2024), technology inclusion enhances students' mathematical reasoning (Yildiz & Arpaci, 2024), problem-solving, and critical thinking skills in the learning of mathematics, leading to positive learning outcomes (Cirneanu & Moldoveanu, 2024; Perienen, 2020). Consequently, integrating technology into teaching will address South African schools' current low mathematics achievement. Saal and Graham (2023) attribute the lack of technology integration to mathematics educators' ignorance of its advantages, such as improving students' learning and academic performance.

Hodges and Prater (2014) identified two forms of obstacles to technology integration in teaching, which are external and internal to the educator. The South African provincial education departments in South Africa have made great strides in resolving this first-order barrier by providing technology resources to targeted poor, disadvantaged township schools; however, challenges such as shortages of devices, poor connectivity, and load-shedding still exist in South African schools (Avci, 2022; Matemera, 2020; Mihai, 2020; Minty & Moll, 2020; Saal & Graham, 2023; Zulu, 2020). Nonetheless, dealing with internal barriers such as lack of confidence and skill, attitude and beliefs, professional development, and lack of technical support has been insurmountable regarding technology integration (Bećirović, 2023). For example, mathematics educators who believe in the effectiveness of traditional teaching methods may be unwilling to utilize digital tools (Ertmer et al., 2012; Gkrimpizi et al., 2023). Furthermore, if traditional methods have proven successful, educators may resist change, aligning with the adage "If it ain't broke, do not fix it" (see Taimalu & Luik, 2019). In addition, educators who do not recognize the value and utility associated with technology may persist in using their conventional methods or may only incorporate it to supplement certain lessons (Johnson et al., 2016). Additionally, integrating technology poses a significant challenge, particularly given the time and effort required to design digitally enhanced lessons (Ertmer et al., 2012).

More importantly, a significant factor hindering the effective incorporation of technology in teaching is the insufficient understanding of relevant pedagogical strategies among educators (Ardiç, 2021; Diseko & Mashiteng, 2020; Graham et al., 2020; Masango et al., 2022; Minty & Moll, 2020; Ndlovu & Meyer, 2019; Taimalu & Luik, 2019; Zulu, 2020). Educators who use student-centered approaches are more disposed to leverage digital tools to enhance their teaching than the ones who use traditional approaches (Taimalu & Luik, 2019). Despite a lack of pedagogy, motivated educators would still explore and engage with the advanced features of IWBs (Mokoena et al., 2022). Furthermore, technology integration in mathematics education is significantly hindered by educators' lack of confidence in their technical skills and knowledge (Avci, 2022; Johnson et al., 2016; Tang et al., 2023; Yuan et al., 2023b; Zulu, 2020). Johnson et al. (2016) and Njiku et al. (2021) reported that educators are "digital immigrants", hence the lack of confidence in using technology in their teaching. Educators who lack confidence in using technology may get intimidated by their knowledgeable students who are "digital natives" and would resort to traditional approaches where they are comfortable rather than feel out of their depth when they use technology. Jarrah et al. (2024) and Zulu (2020) also attribute the lack of confidence to inadequate technical support and technological pedagogical content knowledge (TPACK). However, technical support is limited or nonexistent in many of these targeted poor schools, exacerbating technological integration into mathematics teaching. Consequently, Mokoena et al. (2022) suggested providing technical assistance to strengthen educators' confidence in integrating digital tools into their teaching. With sufficient technological support, educators can dedicate more time and energy to their instructional practices rather than grapple with technological obstacles that erode their teaching time. This is common in these poor, disadvantaged township schools, which lack technical support, leading to frustration with technology use (Johnson et al., 2016). Further, lack of training contributes to apprehension about utilizing technology (Jarrah et al., 2024; Mailizar et al., 2021). For instance, the training the Gauteng Department of Education (GDE) provides their educators is basic and not helpful in integrating technology (Masango et al., 2022; Zulu, 2020). Therefore, there is a need for relevant, continuous professional development focusing on pedagogy required to increase educators' confidence levels (Jarrah et al., 2024).

This underutilization of technology raises important questions about the underlying causes; hence, to understand the lack of utilization of technology by South African mathematics educators, it is important to explore the factors that influence their technology adoption. The robust unified theory of acceptance and use of technology (UTAUT2) by Venkatesh et al. (2012) was used as the overarching theoretical framework to examine the factors influencing technology adoption. The UTAUT2 comprise social influence (SI), habit (HT), hedonic motivation (HM), facilitating conditions (FC), performance expectancy (PE), and effort expectancy (EE) as primary antecedents of behavioral intention (BI) to use technology and HT, FC and BI as predictors of behavioral use (BU). Furthermore, moderators such as age and teaching experience may strengthen these predictor-dependent variable relationships. For instance, younger educators, having recently been exposed to technology in their training colleges, may find integrating technology into their teaching easier than mature educators, as they are generally more tech-savvy.

More importantly, UTAUT2 was extended by including the TPACK proposed by Mishra and Koehler (2006) as a predictor variable of behavioral and actual technology usage. The TPACK framework, as described by Mishra and Koehler (2006), encompasses technological content knowledge (using technology to explain subject matter), technological pedagogical knowledge (using technology to apply various teaching methods), and pedagogical content knowledge (understanding different teaching methods specific to subject matter content). An educator's good balance of TPACK is important for integrating technology effectively in teaching (Schmidt et al., 2009).

Given the limited knowledge about the interplay and dynamics of the factors that influence technology integration in the specific context of Gauteng secondary schools, the study sought to address the following research questions:

- What factors influence the BI and use of technology among mathematics educators in Gauteng secondary schools?
- What are the individual contributions of these factors to technology integration?
- What are the influences of moderators on the significant factors that contribute to technology integration?

By applying the UTAUT2 as the overarching framework and the TPACK as a sub-framework to the context of Gauteng secondary schools, the study will help to determine the key predictors of successful technology integration, leading to the design of targeted interventions to optimize technology integration, thereby enhancing mathematics achievement, which has been appalling in South African schools (Gaillard, 2019; Graham et al., 2021). Additionally, the study is significant because understanding the interplay of internal factors that lead to successful technology integration offers a more holistic approach than merely providing technology to educators, akin to putting the cart before the horse. Lastly, a few studies have used structural equation modelling (SEM) to analyze the acceptance and use of technologies by in-service secondary mathematics teachers in South Africa using the UTAUT2 framework (e.g., Graham et al., 2020) or the TPACK but using correlational analysis (e.g., Spangenberg & De Freitas, 2019). However, there are several studies on descriptive statistical analysis, but neither the UTAUT2 nor TPACK was used (e.g., Netsianda & Ramaila, 2021; Padayachee, 2017; Stols et al., 2015), but a lot of qualitative studies exist. SEM effectively identifies relationships between variables and determines the statistical significance of influential factors. Additionally, SEM can validate the UTAUT and TPACK frameworks in the context of paperless classrooms in South Africa

The following sections provide a detailed theoretical framework and a comprehensive related literature review, leading to the development of the hypotheses.

THEORETICAL FRAMEWORK

Venkatesh et al.'s (2012) UTAUT2, derived from eight models, framed this study. The UTAUT2 comprise SI, FC, HM, HT, price value, EE and PE. **Figure 1** shows the elements of the UTAUT2 theory.

Venkatesh et al. (2003) defined the elements of the UTAUT2: PE as the " degree to which an individual believes that using the system will help him or her to attain gains in job performance", EE as "the degree of ease associated with the use of the system", FC as "the degree to which an individual believes that an organization's and technical infrastructure exists to support the use of the system" SI (social norms [SIN]) as "the degree to which an individual perceives that important others believe he or she should use the new system". SI (descriptive norms [SID]) relates to the extent to which the modelling behavior of other users influences their peers to use a system (De Leeuw et al., 2015). Venkatesh et al. (2012) defined HM as the degree to which a user expects to derive pleasure or enjoyment from using a technology. Price value is a

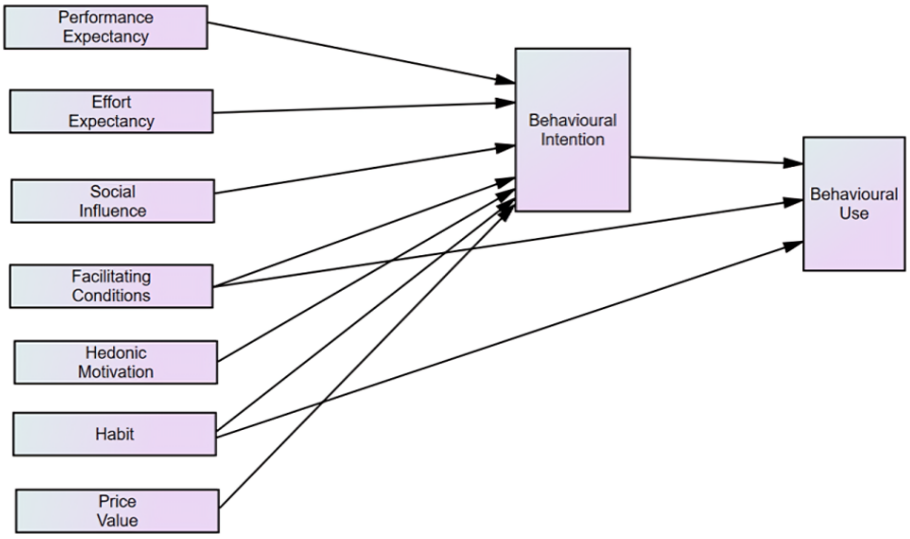

Figure 1. UTAUT2 (adapted from Venkatesh et al., 2012)

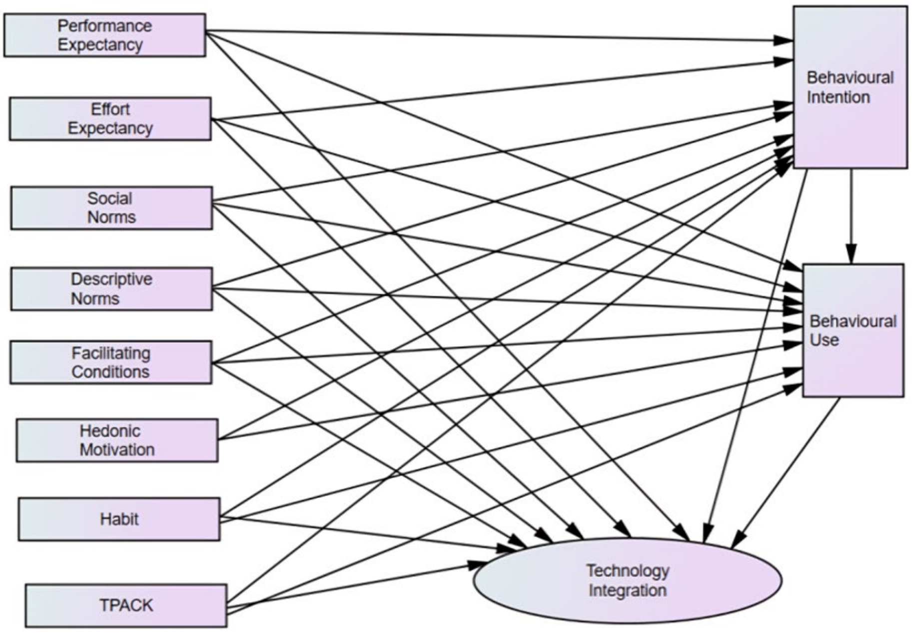

Figure 2. Suggested investigation model (adapted from Venkatesh et al., 2012)

user's assessment of a technology's benefits and associated costs (Venkatesh et al., 2012). HT is the degree to which a user anticipates performing technology-related behaviors without conscious effort (Limayem & Hirt, 2003).

RELATED LITERATURE AND HYPOTHESIS DEVELOPMENT

In this study, the UTAUT2 was modified to include the TPACK construct proposed by Mishra and Koehler (2006). For this study, the price value variable was dropped from the conceptual framework because the GDE provides paperless classroom requirements such as computers, tablets and connectivity in schools. Figure 2 displays the suggested investigation model.

Performance Expectancy

PE has influenced BI to use technology in a developed country. For instance, in China, PE had a statistically significant effect on digital teaching behavior (Tang et al., 2023), usage of dynamic mathematics software in secondary schools (Yuan et al., 2023b) and micro-lecture usage by mathematic educators (Wijaya et al., 2022b). Likewise, in developing countries, similar results have been reported indicating the usefulness of technology in mathematics teaching. For instance, in Turkey and the Philippines, PE influenced the intention to use IWBs, respectively (Bardakcı & Alkan, 2019; De Jesus et al., 2023). Similarly, in Jordan and South Africa, PE influenced the integration of ICT into mathematics teaching (Al-zboon et al., 2021; Graham et al., 2020). Additionally, in Mauritius and Indonesia, PE influenced the acceptance of technology-enhanced classrooms (Pultoo et al., 2020) and the use of digital mathematics textbooks (Wijaya et al., 2022c). However, in China, PE had no significant effect on the use of dynamic software (Yuan et al., 2023b) nor on digital learning resources in Turkey (Avci, 2022).

For this study, PE relates to how mathematics educators believe that using technology in their teaching is useful. For instance, educators who perceive technology as a useful tool in fostering student engagement are likely to use it (Cirneanu & Moldoveanu, 2024; Ozudogru & Ozudogru, 2019). On the contrary, mathematics educators who lack confidence in using technology or perceive the preparation time as excessive may be less likely to recognize the potential gains of using technology in their teaching (Johnson et al., 2016; Minty & Moll, 2020). Moreover, educators who believe that mathematics can be taught with traditional methods may not value the usefulness of technology (Zulu, 2020). In addition, attending to technical glitches, such as troubleshooting faulty equipment, erodes their teaching time and may lead mathematics educators not to see value in digital integration in their mathematics teaching (Mihai, 2020).

This leads to the hypotheses:

H1a: PE did not significantly predict the BI of mathematics educators to use technology in their teaching.

H1b: PE did not significantly predict the mathematics educators’ BU of technology in their teaching.

Effort Expectancy

EE significantly influenced the BI to use technology in different contexts. In China, a developed economy, EE influenced the BI of educators to use dynamic mathematics software (Yuan et al., 2023b). Similarly, EE influenced mathematics educators’ acceptance of technology in developing countries, indicating the importance of user-friendly software interfaces and technical support and training for struggling educators. For instance, in Indonesia, EE influenced the use of digital mathematics textbooks (Wijaya et al., 2022c), the acceptance and use of technology-enhanced classrooms in Mauritius (Pultoo et al., 2020), the acceptance of IWBs in the Philippines (De Jesus et al., 2023) and educators’ integration of ICTs in their teaching in Jordan (Al-zboon et al., 2021). However, EE did not influence the integration of ICTs in mathematics in South Africa (Graham et al., 2020), indicating that the educators found using technology difficult (Mokoena et al., 2022). Similarly, EE did not influence mathematics educators’ digital teaching behavior in China, a developed country (Tang et al., 2023) and educators’ use of digital learning resources in Turkey (Avci, 2022), a developing country.

For this study, EE relates to the extent to which mathematics educators find integrating technology into their teaching easy. Mokoena et al. (2022) and Mailizar et al. (2021) reported that educators lack the skills and training to use the affordances of IWBs and struggle to troubleshoot non-functional devices.

This leads to the hypotheses:

H2a: EE did not significantly predict the BI of mathematics educators to use technology in their teaching.

H2b: EE did not significantly predict the mathematics educators’ BU of technology in their teaching.

Social Influence

Social influence comprises social and descriptive norms (El-Masri & Tarhini, 2017). The influence of SI on the acceptance and use of technology in different technological contexts has been mixed.

In China, SI significantly affected the mathematics educators’ digital teaching behavior (Tang et al., 2023), the acceptance of micro-lectures (Wijaya et al., 2022b), the use of digital mathematics textbooks (Wijaya et al., 2022c) and educators’ intention to implement the flipped classroom model approach in Greece (Plageras et al., 2023). Likewise, in developing countries, SI significantly influenced mathematics educators’ integration of ICTs into teaching. For instance, in Turkey and South Africa, SI (SIN) influenced the integration of ICTs into teaching (Al-zboon et al., 2021; Graham et al., 2020). In addition, SI affected educators’ continued tablet adoption in Kuwait (Aldekheel et al., 2022), mathematics educators’ acceptance of technology-enhanced classrooms in Mauritius (Pultoo et al., 2020) and acceptance of IWBs in the Philippines (De Jesus et al., 2023). However, in China, SI has had no statistically significant effect on the behavioral usage of dynamic software (Yuan et al., 2023b). The same finding applies to using digital learning resources in Turkey, a developing country (Avci, 2022).

Social norms

In this study, SIN shows how significant others helped other mathematics educators integrate technology into mathematics teaching. The significant others who held senior positions did not support the paperless program and were reluctant to use Information communication tools (Matemera, 2020).

This leads to the hypotheses:

H3a: SIN did not significantly predict the BI of mathematics educators to use technology in their teaching.

H3b: SIN did not significantly predict the mathematics educators' BU of technology in their teaching.

Descriptive norms

For this study, SID are how the modelling behavior of other mathematics educators influenced their peers to incorporate technology into their mathematics teaching. The ICT trainers employed to support the educators in using smartboards concentrated on the ICT basics (Mihai, 2020), so the educators did not have the opportunity to reach a high level of pedagogy proficiency to demonstrate modelling behavior through expertise.

This leads to the hypotheses:

H4a: SID did not significantly predict the BI of mathematics educators to use technology in their teaching.

H4b: SID did not significantly predict the mathematics educators' BU of technology in their teaching.

Facilitating Conditions

Several studies from China have indicated that FC significantly influences mathematics educators' BI to use technology. For instance, Yuan et al. (2023b) and Wijaya et al. (2022a) reported that FC influenced the educators' usage behavior of dynamic mathematics software and the acceptance of micro-lectures. Similarly, in a developing country, FC influenced the acceptance of IWBs in the Philippines (De Jesus et al., 2023), the integration of ICTs into education in Mauritius and Jordan (Al-zboon et al., 2021; Perienen, 2020; Pultoo et al., 2020), and educators' continued tablet adoption in Kuwait (Aldekheel et al., 2022).

On the contrary, FC did not influence Chinese mathematics educators' digital teaching behaviors (Tang et al., 2023) and Turkish teacher's use of digital learning resources (Avci, 2022). However, on the actual usage of technology, Zhou et al. (2022) and Avci (2022) reported that FC influenced Chinese mathematics educators' behavioral usage of IWBs and the use of digital learning resources by Turkish educators (Avci, 2022).

In this study, FC relate to the extent of organizational and technical support needed to assist mathematics educators in integrating technology into their mathematics teaching. Loading shedding, connectivity issues, and a lack of digital equipment and technical support meant the educators could not fully integrate technology into their teaching (Matemera, 2020; Minty & Moll, 2020; Mokoena et al., 2022; Saal & Graham, 2023).

This leads to the hypotheses:

H5a: FC did not significantly predict the BI of mathematics educators to use technology in their teaching.

H5b: FC did not significantly predict the mathematics educators' BU of technology in their teaching.

Habit

Empirical evidence suggests HT influenced mathematics educators' BI to integrate technology. In China, HT influenced the BI and use of IWBs (Zhou et al., 2022) and mathematics educators' continuous intention of using micro-lectures (Wijaya & Weinhandl, 2022). Similarly, in developing economies, HT influenced Filipino mathematic educators' acceptance of IWBs and Turkish mathematics educators' s use of digital learning resources (Avci, 2022). On the actual behavioral usage of technology, Avci (2022) reported that HT influenced Turkish educators' BU of digital learning resources for mathematics.

In this study, HT is how mathematics educators exhibited automated behaviors when integrating technology into their teaching. The educators could not use digital devices consistently because of challenges such as poor connectivity, lack of or delayed technical support and load-shedding (Mokoena et al., 2022). Nevertheless, during the COVID-19 pandemic, educators developed desirable HTs towards technology use since they were forced to work online.

This leads to the hypotheses:

H6a: HT did not significantly predict the BI of mathematics educators to use technology in their teaching.

H6b: HT did not significantly predict the mathematics educators' BU of technology in their teaching.

Hedonic Motivation

HM influences BI to use technology in various contexts. In China, HM influences educators' usage behavior of dynamic mathematics software (Yuan et al., 2023b) and BI and use of IWBs in remote and rural areas (Zhou et al. (2022). In Indonesia, HM influenced microgame adoption among secondary school mathematics educators (Wijaya et al., 2022c). In Turkey, HM influenced educators' use of digital learning resources (Avci, 2022). However, motivation did not influence Filipino educators' behavioral acceptance of IWBs (De Jesus et al., 2023). It is worth noting that these studies were not longitudinal and could have been influenced by the novelty of teaching mathematics software, which diminishes over time, rather than by the HM arising from using the software over time.

This leads to the hypotheses:

H7a: HM did not significantly predict the BI of mathematics educators to use technology in their teaching.

H7b: HM did not significantly predict the mathematics educators' BU of technology in their teaching.

Behavioral Intention and Behavioral Use

BI influenced Chinese mathematics educators' digital teaching behavior (Tang et al.,2023), educators' usage behaviors of dynamic mathematics software (Yuan et al., 2023b), the acceptance of micro-lectures (Wijaya et al., 2022b) and the use of IWBs (Zhou et al., 2022). Additionally, BI influences the actual use of digital mathematics textbooks in Indonesia (Wijaya et al., 2022c), educators' use of digital learning resources in Turkey (Avci, 2022) and teacher practice and integration of ICTs in South Africa (Graham et al., 2020). However, BI did not influence the acceptance of whiteboards in the Philippines (De Jesus et al., (2023).

According to Venkatesh et al. (2003), BI leads to BU. However, according to Brookes (2023) and Wieber et al. (2015), BI does not necessarily lead to actual usage. For instance, mathematics educators may not be prepared to invest more time to prepare for mathematics lessons that use technology (Ertmer et al., 2012). In addition, a lack of training and support (Bećirović, 2023), a preference for traditional teaching methods (Ertmer et al., 2012; Gkrimpizi et al., 2023), and limited professional development (Jarrah et al., 2024) may curtail the transformation of BI into actual usage of technology in teaching

This leads to the hypothesis:

H8: BI did not significantly predict the mathematics educators' BU of technology in their teaching.

TPACK

Prior empirical research has shown that TPACK has had mixed effects on mathematics educators' BI to integrate technology. Tang et al. (2023) reported that TPACK predicted secondary school mathematics educators' digital teaching behavior. However, this was not the case in some studies on IWBs (Joo et al., 2018; Wijaya et al., 2022a). However, in the actual usage of IWBs, TPACK influenced the BU of IWBs (Tosuntaş et al., 2021). In addition, TPACK influenced the educators' use of digital resources for teaching mathematical cultures in China (Liu et al., 2024).

In this study, TPACK is the degree to which mathematics educators' TPACK level helped them use technology in their mathematics teaching. Lack of sound TPACK skills (Diseko & Mashiteng, 2020; Graham et al., 2020; Johnson et al., 2016; Zulu, 2020) forced educators to use educator-centered strategies rather than learner-centered ones. In addition, mathematics educators use basic features of digital resources because they lack a combination of TPACK strategies (Mihai, 2020).

This leads to the hypotheses:

H9a: TPACK did not significantly predict the BI of mathematics educators to use technology in their teaching.

H9b: TPACK did not significantly predict the mathematics educators' BU of technology in their teaching.

The Influence of Moderators

According to Al-zboon et al. (2021), age, qualifications, and experience did not impact using digital tools in mathematics teaching. However, age influenced the educators' continued adoption of tablets in Kuwait (Aldekheel et al., 2022) and the relationship between PE and BI (De Jesus et al., 2023). Gender and teaching experience did not influence mathematics educators' BU of digital software (Yuan et al., 2023b). However, gender influenced educators' incorporation of technology in mathematics (Aldekheel et al., 2022; Al-zboon et al., 2021).

METHODOLOGY

Research Design

We used a non-experimental, cross-sectional, correlational quantitative study utilizing the SEM approach to analyze the complex relationships between the variables. Unlike a longitudinal study, which measures the occurrence of an event multiple times, a cross-sectional study allows measurements to be taken at a single point in time (Grujicic & Nikolic, 2021), therefore making the study quick and cost-effective (Wang & Cheng, 2020). The quick turnaround time of cross-sectional studies enables interventions to be implemented quickly based on the findings (Kim, 2023). Further, a cross-sectional correlational study makes it possible to find the relationships between the constructs but cannot establish causal relationships between variables (Apuke, 2017).

Participants

The participants in this research are predominantly secondary mathematics educators from schools in townships and suburban areas within the environs of the City of Johannesburg in the Gauteng province of South Africa. Township schools are no-fee-paying institutions, while suburban schools operate as low-fee-paying establishments. The schools are classified into quintiles, with quintile 1 representing economically disadvantaged schools and quintile 5 comprising affluent institutions. The study involved a total of 309 mathematics educators.

Table 1 depicts the educators' gender, age, teaching experience, school quintile, qualification, and grade taught. Almost equal numbers of females and males participated in the study; the common age group was 40–49. The teaching experience was evenly distributed among the groups; most educators came from quintile two schools, and bachelor's and Honors degrees were the most common qualifications. Educators taught across grades.

Instruments

The questionnaire comprised two main parts: biographical information (such as age, gender, teaching experience, school quintile, and grade taught) and combined UTAUT2 and TPACK items. The UTAUT2 instrument was adopted from the one used by Venkatesh et al. (2012). The constructs from Venkatesh et al. (2012) were PE (6 items), EE (3 items), SIN (3 items), SID (3 items), FC (6 items), HM (3 items), HT (3 items), BI (3 items) and BU (4 items). The second instrument was adopted from Mishra and Koehler's (2006) TPACK framework. The TPACK had four items. The items from Venkatesh et al. (2012) and Mishra and Koehler (2006) measure mathematics educators' BI and use of technology in their teaching. The survey instrument used a 6-point Likert scale ("1 = strongly disagree; 2 = disagree; 3 = somewhat disagree; 4 = somewhat agree; 5 = agree; 6 = strongly agree"). A 6-point Likert scale was employed to alleviate respondent bias towards neutral responses, forcing the respondents to choose a more definitive stance (Kankaraš & Capecchi, 2024). The researchers carefully checked the items' wording to ensure content validity. Statistical analyses were undertaken to measure convergent (relatedness of items/constructs) and discriminant validity (distinctness of items/constructs) for construct validity (see following sections).

Table 1. Biographical information for the educators

Variables		Frequency	Percentage
Gender	Female	150	48.5
	Male	159	51.5
	Total	309	100
Age	20–29	40	12.9
	30–39	70	22.7
	40–49	101	32.7
	50–59	86	27.8
	60–65	9	2.9
	> 65	3	1.0
	Total	309	100
Teaching experience	1	6	1.9
	2–5	46	14.9
	6–10	49	15.9
	11–15	48	15.5
	16–20	43	13.9
	21–25	50	16.2
	26–30	36	11.7
	>30	31	100
	Total	309	100
Quintile	1	67	21.7
	2	126	40.8
	3	74	23.9
	4	42	13.6
	5	0	0
	Total	309	100
Qualification	Higher certificate	2	.6
	Diploma	21	6.8
	Bachelor’s	117	37.9
	Honors’	133	43.0
	Master’s	29	9.4
	Doctorate	7	2.3
	Total	309	100
Grade taught	7	51	16.5
	8	108	35
	9	130	42.1
	10	205	66.3
	11	211	68.3
	12	221	71.5
	Total	309	100

Data Collection

The Johannesburg region comprises quintile 1 to 5 schools, where quintile 1 is economically disadvantaged and quintile 5 is economically advantaged. Not all schools have paperless classrooms in the Johannesburg region, so schools with paperless classrooms were purposively sampled because mathematics educators in these schools were expected to use technology. The researchers visited schools, sought permission from the headmasters, and provided the link to the survey to the educators who were willing to participate. It is worth noting that ethical clearance had been sought and granted by the university ethical committee and the department of basic education to carry out this study. Data was collected from mathematics educators who taught grades 7 to 12 in selected schools using an online Google Form.

DATA ANALYSIS

Sample Size and Power Analysis

A power analysis was conducted using **G*Power 3.1.9.7** to determine the sample size required to test the relationships between eight predictors (PE, EE, SIN, SID, FC, HM, HT, and TPACK) and the dependent variable, BI. The analysis used the “linear multiple regression: fixed model, R^2 increase” option, with a medium effect

Table 2. Factor loadings for each construct

S/N	PE	EE	SIN	SID	FC	HM	HT	BI	TPACK	BU
1	.800	.947	.964	.826	.762	.932	.889	.980	.831	.951
2	.793	.893	.850	.782	.710	.865	.889	.945	.804	.840
3	.790	.842	.842	.611	.696	.859		.870	.758	.789
4	.754				.694				.704	.652
5	.696				.693					
6	.682				.590					

Table 3. KMO values of the constructs

Construct	KMO
PE	.865
EE	.746
SIN	.729
SID	.680
FC	.839
HM	.750
HT	.500
BI	.743
TPACK	.816
BU	.795

Table 4. Correlations among the constructs

	HM	BU	SIN	PE	EE	SID	BI	FC	TPACK	HT
HM	1									
BU	.347	1								
SIN	.468	.306	1							
PE	.485	.265	.375	1						
EE	.468	.389	.474*	.440*	1					
SID	.306	.301*	.416	.293	.392	1				
BI	.572	.279	.325	.519	.431	.325	1			
FC	.328	.547	.388	.335	.602	.426	364	1		
TPACK	.610	.473	.408	.451	.505	.391	.579	.443	1	
HT	.451	.596	.398	.389	.389	.376	.373	.479	473**	1

size ($f^2 = 0.15$), a significance level of $\alpha = 0.05$ and a desired power ($1-\beta$) of 0.80, the analysis indicated that a minimum sample size of **152** was required. The dependent variable, BU, needed a minimum of **158** participants, and the dependent variable, Technology adoption, needed a minimum of **164** participants. This ensured sufficient power to test the collective influence of all predictors. To ensure sufficient power, **309** participants participated in the study.

Exploratory Factor Analysis

We used SPSS version 29 to analyze the survey items and explore their unidimensional extent. The resultant factor loadings from the exploratory factor analysis exceeded the threshold of 0.5, suggesting they were strongly related to their parent constructs (Field, 2018). **Table 2** shows the factor loadings.

Sampling adequacy

The Kaiser-Meyer-Olkin (KMO) was used to measure sampling adequacy. The KMO values for each construct except for SID and HT were greater than 0,7, indicating that exploratory factor analysis was plausible (Backhaus et al., 2016). However, for Kaiser (1974), KMO values greater than 0.5 are adequate. **Table 3** shows the KMO values.

Multicollinearity

Multicollinearity measures how the constructs are correlated with each other (Streukens & Leroi-Werelds, 2023). The inter-construct correlations are less than 0.8, indicating little or no multicollinearity (Field, 2009). **Table 4** shows the correlations among the constructs.

Table 5. KMO and Cronbach's alpha values

Construct	Cronbach's alpha	Number of items
PE	.885	6
EE	.922	3
SIN	.914	3
SID	.779	3
FC	.840	6
HM	.916	3
HT	.881	2
BI	.951	3
TPACK	.854	4
BU	.876	4

Table 6. Convergent and discriminant validity measurements

	HM	BU	SIN	PE	EE	SID	BI	FC	TPACK	HT
HM	.916	.785	**.890**							
BU	.886	.665	.347	**.815**						
SIN	.917	.787	.468	.306	**.890**					
PE	.887	.569	.485	.265	.375	**.754**				
EE	.923	.801	.468	.389	.474	.440	**.895**			
SID	.787	.556	.306	.301	.416	.293	.392	**.746**		
BI	.952	.870	.572	.279	.325	.519	.431	.325	**.933**	
FC	.846	.480	.328	.547	.388	.335	.602	.426	364	**.692**
TPACK	.840	.637	.610	.473	.408	.451	.505	.391	.579*	.443
HT	.690	.527	.451	.596	.398	.389	.389	.376	.373	.479

Reliability

For reliability, we used Cronbach's alpha to measure the internal consistency, and all the Cronbach's alpha values exceeded 0.8, signifying good reliability (Tavakol & Dennick, 2011). **Table 5** shows the sampling adequacy and reliability values.

Construct Validity

Construct validity is evaluated by examining both convergent and discriminant validity, which are assessed using composite reliability (CR) and average variance extracted (AVE) (Fornell & Larcker, 1981; Hair et al., 2006). CR assesses the overall consistency of a group of related but distinct items, whereas AVE measures the variance in a construct explained by the construct relative to measurement error (Fornell & Larcker, 1981; Hair et al., 2006). In **Table 6**, the CR and AVE values meet the recommended thresholds of 0.7 and 0.5, respectively, for convergent validity (Hair et al., 2006). Discriminant validity is also established since the inter-construct correlations are lower than the square roots of the AVEs (Fornell & Larcker, 1981). **Table 6** shows the convergent and discriminant validity measures of the constructs.

Confirmatory Factor Analysis

The AMOS version 29 software was used to verify the measurement model. **Figure 3** shows the confirmatory factor analysis model.

The model fit indices, comparative fit index (CFI = .902) and incremental fit index (IFI = .902), except for the Tucker Lewis index (TLI = .893), exceeded the threshold of .90 and the CMIN/df (2.485) was between 1 and 3, signifying a reasonable model (Hu & Bentler, 1999). Further, the root mean square error of approximation (RMSEA) was equal to .069, and a value less than .08 is reasonable (Hu & Bentler, 1999). **Table 7** shows the cut-off criteria for fit indices.

Descriptive statistics

The mathematics educators endorsed BI as the highest (mean of 5.347) and HT as the least (mean of 4.100). PE was endorsed as the second highest (mean 5.147), probably indicating that educators know the usefulness of integrating technology into their mathematics teaching. **Table 8** shows the means and standard deviations of the constructs.

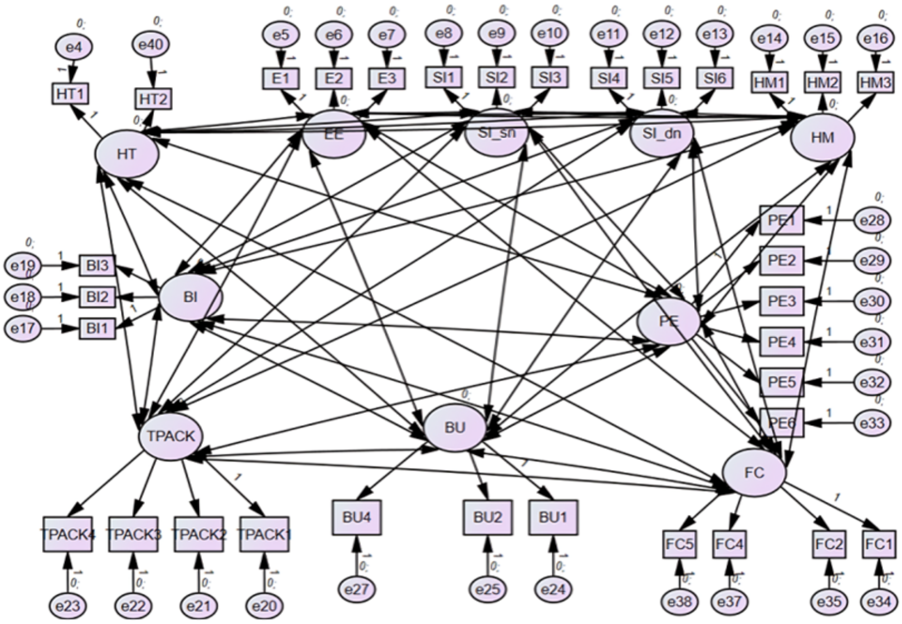

Figure 3. Confirmatory factor analysis model (Created by authors based on study results)

Table 7. Model fit measures

Measure	Observed value	Recommended	Interpretation
CMIN/df	2.485	Greater than 1 but less than 3	Acceptable
CFI	.902	≥ .90	Acceptable
TLI	.893	≥ .90	Poor
IFI	.902	≥ .90	Acceptable
RMSEA	.069	≤ .08	Excellent

Table 8. The means and standard deviations for all the constructs

Variable	Mean	Standard deviation
PE	5.147	.831
EE	4.936	.993
SIN	4.718	1.031
SID	4.188	1.062
FC	4.514	.905
HM	5.140	.819
HT	4.100	1.290
BI	5.347	.817
TPACK	4.972	.782
BU	4.374	1.080

Structural Analysis

SEM was employed to analyze the relationships between the constructs. **Figure 4** depicts the structural analysis model.

In **Table 9**, *H1a*, *H6a*, and *H9a* were rejected, indicating that PE, HM, and TPACK influenced the BI of mathematics educators to incorporate technology in their teaching. *H9b*, *H5b*, *H4b*, *H2b*, and *H7b* were rejected, indicating that EE, FC, SID, HT and TPACK influenced the BU of mathematics educators to integrate technology into their teaching (see **Table 9**).

Table 9 shows the relationship among the constructs.

Second-order confirmatory factor analysis

In **Table 6**, the constructs have convergent validity, suggesting that a second latent factor accounts for these constructs (Brown, 2006). We employed second-order confirmatory factor analysis to determine the relationship between the constructs and the newly proposed latent factor, technology Integration.

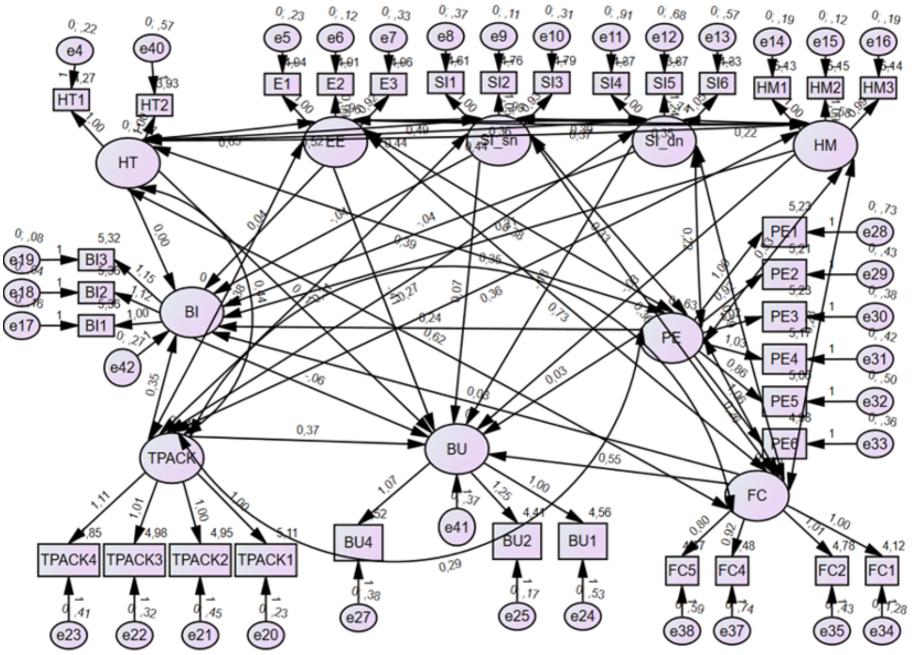

Figure 4. Structural analysis model (Created by authors based on study results)

Table 9. Path analysis

Hypothesis	Path	Standardized estimate	p	Result
H7a	BI ← HT	−.007	.918	Supported
H2a	BI ← EE	.058	.614	Supported
H3a	BI ← SIN	−.054	.363	Supported
H4a	BI ← SID	−.043	.505	Supported
H6a	BI ← HM	.222	.002	**Rejected**
H1a	BI ← PE	.259	***	**Rejected**
H5a	BI ← FC	.039	.749	Supported
H9a	BI ← TPACK	.333	***	**Rejected**
H8	BU ← BI	−.046	.491	Supported
H9b	BU ← TPACK	.272	.002	**Rejected**
H5b	BU ← FC	.529	***	**Rejected**
H2b	BU ← EE	−.427	***	**Rejected**
H3b	BU ← SIN	.072	.248	Supported
H4b	BU ← SID	−.166	.018	**Rejected**
H6b	BU ← HM	−.027	.717	Supported
H1b	BU ← PE	.024	.725	Supported
H7b	BU ← HT	.530	***	**Rejected**

Figure 5 shows the analysis.

Table 10 shows the influence of predictor variables on technology integration.

All the constructs had a statistically significant influence on technology integration but varying explained variance. TPACK contributed the most explained variance to technology integration, followed by EE, FC, motivation and HT in diminishing order. SI (SIN and SID) contributed the least explained variance.

ANOVA Test for Moderators

Using the ANOVA test, all the moderators; age, gender, qualification, grade taught, and teaching experience did not influence the constructs, PE, HM, TPACK, and BI.

DISCUSSION

The study used the UTAUT2 as the overarching framework and the TPACK sub-framework to determine the factors influencing mathematics educators' BI and use in integrating technology into their teaching. The results are discussed in the following sections.

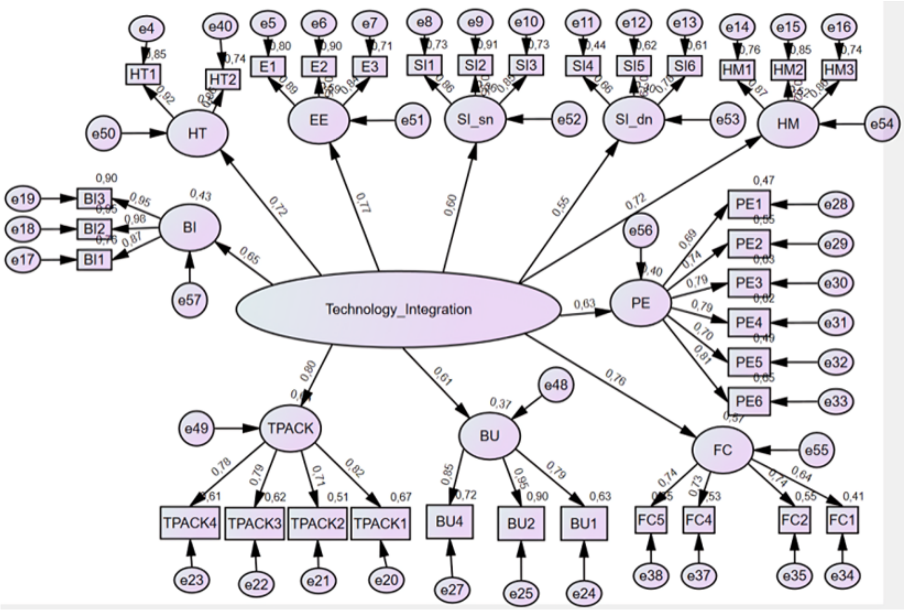

Figure 5. Technology integration analysis (Created by authors based on study results)

Table 10. The influence of predictors on the analysis

Relationship	Standardized estimate	Sig.	Explained variance %	Rank
TPACK ← Technology integration	.803	***	64.4	1
EE ← Technology integration	.771	***	59.5	2
FC ← Technology integration	.758	***	57.4	3
HM ← Technology integration	.720	***	51.8	4
HT ← Technology integration	.716	***	51.3	5
BI ← Technology integration	.654	***	42.8	6
PE ← Technology integration	.635	***	40.3	7
BU ← Technology integration	.610		37.2	8
SIN ← Technology integration	.597	***	35.7	9
SID ← Technology integration	.549	***	30.1	10

Significant Factors That Influence Behavioral Intention to Integrate Technology

We sought to determine the factors that predicted the BI of mathematics educators to incorporate technology into teaching. The findings indicated that HM, PE and TPACK were significant predictors. The results for each construct are discussed in the following sections.

HM influenced BI to use technology in teaching mathematics, resonating with findings from previous studies (Avci, 2022; Wijaya et al., 2022a; Yuan et al., 2023a; Zhou et al., 2022). The implication is that if the educators are motivated, they will try to use technology in their mathematics teaching. PE influenced BI to incorporate technology into mathematics teaching, agreeing with findings from several authors (Al-zboon et al., 2021; Bardakcı & Alkan, 2019; De Jesus et al., 2023; Graham et al., 2020; Pultoo et al., 2020; Tang et al., 2023; Wijaya et al., 2022a, 2022b; Yuan et al., 2023a). It is worth noting that if technology is deemed useful, educators will likely use it. Nevertheless, this result does not align with the views of several authors (Masango et al., 2022; Saal & Graham, 2023), who indicated that some mathematics educators did not find integrating ICTs useful in teaching mathematics. TPACK influenced BI to integrate technology into teaching, supporting the findings from Tang et al. (2023) but disagreeing with those from Wijaya et al. (2022b) and Joo et al. (2018). Having pedagogical skills will help educators plan and use technology effectively to support learning outcomes and enhance student achievement in mathematics, as reported by Mailizar et al. (2021) and Ndlovu and Meyer (2019).

Non-Significant Factors That Influence Behavioral Intention to Integrate Technology

The HT construct did not influence BI to use technology, disagreeing with earlier findings (Avci, 2022; De Jesus et al., 2023; Wijaya & Weinhandl, 2022; Zhou et al., 2023). This indicates that educators do not have "technology HTs" or are not using technology for teaching, aligning with the views of Johnson et al. (2016) and Njiku et al. (2021), who reported that educators are "digital immigrants" and lack confidence in using technology.

EE did not predict the BI to use technology in mathematics, and this result agrees with findings from Tang et al. (2023) but disagrees with findings from several authors (De Jesus et al., 2023; Pultoo et al., 2020; Wijaya et al., 2022b; Yuan et al., 2023a). This result aligns with the findings from several authors (Masango et al., 2022; Zulu, 2020) who reported that the GDE provided their educators with basic training on using IWBs and educators are likely to struggle when using technology in their teaching. Furthermore, the result aligns with the findings of Saal and Graham (2023) and Mokoena et al. (2022), who reported a lack of continuous professional development among mathematics educators. Hence, the teachers are not continuously developed in using technology and may find it difficult to handle.

SI (SIN) did not influence BI, collaborating with Yuan et al.'s (2023b) findings but disagreeing with earlier studies (Aldekheel et al., 2022; Al-zboon et al., 2021; De Jesus et al., 2023; Graham et al., 2020; Plageras et al., 2023; Pultoo et al., 2020; Tang et al., 2023; Wijaya et al., 2022a; Yuan et al., 2023b). In addition, the result aligns with the views of Matemera (2020), who reported that significant others who held senior positions did not support the paperless program and were reluctant to use ICTs in their teaching.

FC did not predict the BI to integrate technology into mathematics teaching, disagreeing with findings from several authors (Aldekheel et al., 2022; De Jesus et al., 2023; Perienen, 2020; Pultoo et al., 2020). This result is unsurprising since the chosen schools had connectivity and digital equipment; hence, FC were not expected to influence BI to integrate technology into teaching (see Dlamini, 2022; Mlambo et al., 2020).

Factors That Influence Behavioral Use to Integrate Technology

The TPACK influenced the BU of integrating technology into mathematics in line with findings from Tosuntaş et al. (2021) and Liu et al. (2024). In addition, this result aligns with the views of several authors (Ardiç, 2021; Diseko & Mashiteng, 2020; Graham et al., 2020; Masango et al., 2022; Minty & Moll, 2020; Ndlovu & Meyer, 2019; Taimalu & Luik, 2019; Zulu, 2020) who highlighted the importance of TPACK in technology use.

FC predicted the educators' BU of technology in teaching mathematics, aligning with Johnson et al.'s (2016), Tang et al.'s (2023) and Zhou et al.'s (2022) findings. It is worth noting that because of the erratic power cuts during this study, connectivity would sometimes be problematic in schools without electric generators. In addition, this result resonates with the views of Masango et al. (2022) and Zulu (2020), who highlighted inadequate technical support to help educators troubleshoot faulty equipment. In addition, this result aligns with the views of several authors (Avci, 2022; Matemera, 2020; Mihai, 2020; Minty & Moll, 2020; Saal & Graham, 2023; Zulu, 2020) who lamented the lack of connectivity and unreliable electricity due to load-shedding in South Africa. Further, the result disagrees with the findings from Wijaya et al. (2022a) in a developed country where there are no power shortages in China in their study of the influence of FC on micro-lecture usage by mathematics educators in China.

EE influenced the educators' BU of technology, supporting the findings from Al-zboon et al. (2021), Perienen (2020), and Yuan et al. (2023b) but contradicting those from Graham et al. (2020) and Tang et al. (2023). HT influenced the BU of technology, concurring with findings from Avci (2022). SI in the form of SID influenced the BU of technology. This result mirrors the view of Johnson et al. (2016), who highlighted the importance of digitally competent educators who can act as role models for other digitally incompetent educators.

Factors That Did Not Influence Behavioral Use to Integrate Technology

PE did not predict the mathematics educators' BU of technology, echoing Yuan et al.'s (2023b) finding and aligning with the views of Johnson et al. (2016), who lamented the failure of educators to recognize the value and utility associated with technology in their teaching. The preference for traditional teaching methods probably affected the integration of technology into mathematics teaching, aligning with the views of Ertmer et al. (2012) and Gkrimpizi et al. (2023), who indicated that educators who use traditional approaches to teaching methods may be unwilling to utilize digital tools. Further, more time is needed to prepare lessons incorporating technology (Ertmer et al., 2012) hence diminishing the importance of technology use. In addition, there is a lack of training and support (Bećirović, 2023). Hence, educators may find technology a nuisance and less useful.

BI did not predict the BU of technology, agreeing with De Jesus et al.'s (2023) findings but disagreeing with earlier studies (Avci, 2022; Graham et al., 2020; Tang et al., 2023; Wijaya et al., 2022a; Yuan et al., 2023a; Zhou et al., 2022). This result seems counterintuitive but aligns with the views of Brookes (2023) and Wieber et al. (2015), who reported that BI might not necessarily translate into actual technology integration because of various barriers such as time constraints, a lack of professional development, a lack of training and support, and a preference for traditional teaching methods, which seems to be the case in this study.

SI (SIN) predicted the BU of technology, and this result is congruent with findings from Yuan et al. (2023b). Motivation did not predict the BU of technology in mathematics teaching, which aligned with findings from De Jesus et al. (2023) and Zhou et al. (2022). In addition, this result mirrors the views of Saal and Graham (2023) and Mokoena et al., 2022), who reported that mathematics educators were frustrated by a lack of technical support, continuous professional development, digital equipment and connectivity.

Contribution of Each Construct to Technology Integration

Regarding the individual contributions of the factors to technology integration, the second-order SEM indicated the most important constructs that contributed more than 50% of each of the explained variances to technology integration were TPACK (64.4%), EE (59.5%), FC (57.4%), HM (51.8%) and HT (51.3%) in diminishing order. BI (42.8%), PE (40.3%), BU (37.2%), SIN (35.7%), and SID (30.1%) contributed less than 50% of explained variance to technology integration.

The Influence of Moderators

In this study, age, teaching experience, gender, school quintile, and qualification did not moderate the BI and BU of technology. For gender and teaching experience, the results concur with findings from Yuan et al. (2023b) and Aldekheel et al. (2022) but disagree with those from Al-zboon et al. (2021). For age, qualifications and experience, the results are consistent with those of Al-zboon et al. (2021). The lack of differentiation, for instance, among young and old educators, inexperienced and experienced educators, and the lowest and most highly qualified educators, is a cause of concern for integrating technology and will need serious investigation. For instance, one would have expected young educators to integrate technology better than old educators since they are "fresh" from training colleges.

Practical contribution

TPACK contributed the most explained variance to technology integration, suggesting that the department of education and school heads provide continuous professional development courses on using smartboards and related equipment. EE contributed the second most explained variance, highlighting the importance of continuous professional development training for educators to have confidence in using technology. FC contributed the third most explained variance to technology integration, buttressing the importance of investing in stable connectivity infrastructure, technological resources, technical support and user support to foster smartboard usage. SI had the least contribution to technology integration, highlighting the need for mathematics educators to form communities of practice at the school or district level and learn from their significant others on smartboard usage.

Limitations of the Study

Three hundred and nine students participated in the study; however, an even larger sample of upward of 600 participants is desirable for the reliability of statistical analyses. The study was quantitative and, on its own, may fail to capture the rich information derived from a mixed method approach where the qualitative data will provide depth and width to the study. In addition, a longitudinal study must be employed to capture the changes in technological integration over time.

CONCLUSION

The study sought to determine the factors that predicted the BI of mathematics educators to incorporate technology into teaching. The findings indicated that HM, PE, and TPACK predicted the BI to use technology in mathematics teaching. TPACK, FC, EE, SID, and HT influenced the BU to integrate technology into mathematics teaching. The second-order structural modelling indicated that all the constructs contributed to technology integration. However, TPACK was the most important, with the highest explained variance of 64.4%, followed by EE at 59%, facilitating at conditions at 57.4%, HM at 51.8%, and HT at 51.3%. Although the GDE provided the schools with technological resources, without technical skills and pedagogy, these resources become a white elephant if the teachers cannot integrate them into their teaching. In addition, the applications(software) must have user-friendly interfaces, and technical support must be provided so educators can optimize using digital resources in their mathematics teaching. The other constructs (BI [42.8%], PE [40.3%], BU [37.2%], SIN [35.7%], and SID [30.1%]) accounted for less than 50% of the explained variance, hence painting a dismal picture of technology integration in these South African schools.

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Declaration of interest: The authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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